

University of Alberta

**MOTOR SKILLS IN INFANCY: EXPLORING THE VARIABILITY OBSERVED IN
TYPICAL DEVELOPMENT**

by

Cynthia Maria Tom



**A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment
of the requirements for the degree of Masters of Science**

Department of Occupational Therapy

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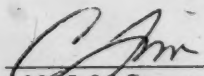
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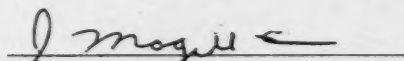

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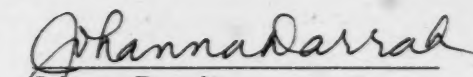
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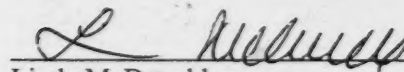
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Abstract

This study used secondary data analyses to examine the gross and fine motor performance of typically developing English-speaking infants with suspicious motor performance scores. Assessed at 9, 11, 13, 16 and 21 months of age, these 33 infants had at least two instances where their scores were more than one standard deviation below the mean on either the gross or fine motor scale of the Peabody Developmental Motor Scales. They were compared to 72 control infants to examine possible explanations for suspicious scores. The groups did not differ for socio-economic status or number of illnesses. Their averaged scores over the five assessments indicated that they have significantly lower motor performance than the controls. There were some indications that their scores may be more variable. There was no evidence that competition between the development of the two motor domains leads to suspicious scores. The developmental trajectories for these infants are described.

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Introduction

It is common as well as recommended practice for professionals providing health services for infants and young children to evaluate motor performance based on standardized measurement tools. Although clinicians do not typically rely solely on these results, standardized tests are frequently used to confirm suspicions or identify children who may have more subtle motor delays. In addition to this, qualification for intervention services and decisions regarding the need for follow-up are often highly influenced by the comparison of a child's score to a normative sample of same-aged peers. The underlying assumption of this practice is that single occasion testing predicts, to some degree, future risks for developmental delay. A child who scores significantly below his or her peers on a single occasion (based on an accepted cut-off score) may be considered to be delayed or at-risk for delay based on the discrepancy of their performance from a statistically determined 'typical' range and intervention services are often recommended.

However, a recent longitudinal study of infant development has identified a high degree of instability in the motor performance of infants who are typically developing (Darrah, personal communications, February, 2002). In fact the *mean* range of percentile ranked scores for these infants within a one-year period (9 to 21 months) is 39 for both gross motor and fine motor skills (with a standard deviation of 14). Clearly this amount of variability in the motor performance of typically developing infants brings into question the validity of single occasion testing for infants and challenges widely held assumptions regarding the stability of motor performance. Typically developing infants may be needlessly labeled causing stress and inconvenience to families.

The present study examined the longitudinal motor performance of infants who would have been labeled *suspicious* through single occasion testing. Although these infants were considered to be typically developing (see criteria below) they scored one standard deviation below the mean on standardized tests of motor performance (fine or gross motor) at least twice out of five assessment occasions. This study examined the longitudinal trajectories of fine motor and gross motor skill development for these infants over the period of one year in an attempt to further understand why typically developing infants obtain suspicious scores. This study included visual analysis of individual profiles and pairs of profiles (fine and gross motor), as well as statistical analyses that involved grouping infants with low scores and comparing them to other typically developing infants. The following questions were addressed:

- 1) Are these infants demonstrating low-average motor skills over this time period, resulting in occasional 'dips' into the suspicious scoring range?
- 2) Are they demonstrating higher degrees of variability in motor performance than other typically developing infants, resulting in widely fluctuating scores that dip into low scoring ranges but also rebound significantly?
- 3) Is there a relationship between fine motor and gross motor skill development that may provide some explanation for the instability observed?

For this study the following definitions were used:

Typically developing infants = considered low-risk for developmental concerns at 8 months (full-term, no medical or parental concerns regarding the infant's development) successfully passed an infant screening test following the study (at 23 months)

Low scoring infants = infants who score below average

(more than one standard deviation below the mean) on at least 2 occasions for either gross or fine motor performance

Comparison group = infants who do not meet the low scoring criteria

Literature Review

Assessment of Infant Motor Development

Prior to the advent of the dynamic systems theory it was assumed that the central nervous system was largely responsible for the development of motor skills. As early as the 1920s, researchers such as Arnold Gesell examined in detail the commonalities noted in the developmental sequence of motor skill acquisition for typically developing infants (Gesell, 1928). Many currently used measures are based on the developmental sequences described in this early research.

Since these early studies there has been substantial interest in identifying deviations in early motor development (Piper & Darrah, 1994). Of particular concern have been those infants who are considered to be *at-risk* for delayed or abnormal development. This would include infants born premature, with low birth weight, cerebral damage (prenatal or perinatal), or abnormal neurological symptoms (Pakula & Palmer, 1997). Prediction of motor outcomes however, has been more successful for infants who have been severely compromised than for less severely compromised infants (Spreen, Risser & Edgell, 1995).

Piper (1993) suggests that the primary concern of most infant screening tools is not their ability to identify infants who will be abnormal (sensitivity) but rather in their ability to discriminate those who will be normal (specificity). A possible explanation may

be that some typically developing infants experience early trauma (early birth, illness, brain insult) but overcome these effects in later infancy or early childhood (Fetters & Tronick, 2000). Another explanation may be that these infants are typically developing and are simply scoring lower due to the natural variability associated with motor development (Fetters & Troniuk).

New infant assessment tools continue to be developed in an attempt to identify key factors that may be better predictors of motor outcomes (Frisone et al., 2002; Harris & Daniels, 2001; Nickel, Renken & Gallenstein, 1989; Piper & Darrah, 1994). However, Fetters and Tronick (2000) report that prediction remains difficult even when quality of movement observations and soft neurological signs are used. In an attempt to balance the trade off between sensitivity and specificity, some assessment tool authors have specifically adjusted cut-off scores so the consequences of over- and under-identification could be minimized (Darrah, Redfern, Maguire, Beaulne & Watt, 1998).

Possible explanations for poor predictive validity may be the high degree of variability in performance for less severely compromised infants and the heterogeneous nature of these infants as a group. Piper, Mazer, Silver and Ramsey (1988) found "slightly more than one-half" (p. 26) of infants with suspicious neurological or developmental assessments at 12 months were considered normal at 24 months. Piper, Byrne, Darrah and Watt (1991) report relatively low rates of consistent normal/abnormal categorization of at-risk infants at term, four months and 18 months based on neurological assessment. Even *hard* measures such as cranial ultrasound scan that have been used to identify the presence or absence of minor brain lesions have lead to relatively low predictive accuracy of later motor or neurological functioning (Jongmans,

Mercuri, de Vries, Dubowitz & Henderson, 1997). Only one third of infants with "persistent flares on neonatal sonography" (p. F13) demonstrated perceptual motor problems or minor neurological signs at six years of age. Conversely, 34% of infants with normal scans had abnormal or borderline performance on tests of motor performance and 13% had abnormal visual-motor test results (Jongmans et al.). These observations and the difficulty with predicting motor outcomes from infancy may be partially explained by the perspective of motor development within the dynamic systems theory.

Dynamic Systems Theory of Motor Development

Within the dynamic systems theory of motor development, motor performance results from the interaction and *self-organization* of several subsystems within the individual, including the somatosensory system, the musculoskeletal system, affect, and cognition (Kamm, Thelen & Jensen, 1990). Thelen et al. (1993) suggest that perceptual-motor skills do not follow a predetermined program but instead are "softly assembled" (p. 1084) and *discovered* through an ongoing process during which individuals explore their specific intrinsic properties within the external environment around them with the intent of solving functional problems (e.g., getting a toy). Following the discovery of a movement pattern that results in an 'in-the-"ball-park"' (Thelen et al., p. 1090) result, the system self-organizes to produce optimal, flexible (scaled to meet the demands of specific tasks) and more consistent (stable) solutions to functional problems. Within this self-organizing process, motor skill development is not simply driven by brain development but also shaped by the experiences and task context afforded to the individual.

Thelen and her colleagues were able to provide support for this theory by demonstrating how infant behaviors assumed to be *hard-wired*, or under strong CNS control (i.e., reflexes), could be influenced by biomechanical factors. For instance, Kamm et al. (1990) have shown that it is possible to inhibit 'primary stepping' by providing infants with the experience of having small weights attached to their legs (equal to the weight gain expected in that limb at four to six weeks). Following the removal of these weights, primary stepping was discontinued despite infants being at an age appropriate for this reflex. These authors were also able to demonstrate that it is possible to prolong primary stepping in infants who are submerged in water (having the effect of relieving the weight of the legs) (Kamm et al.). Other studies related to how infants learn to reach report very different and seemingly individualized methods used by typically developing infants to solve the problem of reaching for a toy (Thelen et al., 1993). Patterns of muscle activation, hand trajectories and joint angles are widely different among typically developing infants when they first discover how to successfully reach for a toy (Thelen et al.). One of the primary commonalities suggested by the researchers for these infants prior to initial success with reaching was having the intent to reach (i.e., functional goal). The means for achieving the goal was then flexibly assembled.

Also important to the understanding of dynamic systems theory is the principle of nonlinearity. Nonlinearity refers to the concept that small changes can have substantial effects (Kamm, Thelen & Jensen, 1990). Kamm et al. explain this concept by describing the "last straw" analogy, how it is possible for the weight of one straw to influence a camel's ability to support a large load. Eventually the "last straw" causes the animal to collapse. Nonlinearity in motor development would be observed at transitional points in

development when new motor skills are about to emerge. Kamm et al. suggest that nonlinearity in development may be observed partly due to the "asynchrony of the developmental course of the subsystems that comprise it" (Kamm et al., 1990. pp. 772).

Given this view of motor development as a self-organizing, nonlinear process influenced by a number of individual, environmental and task variables, it is not surprising that prediction of motor outcomes is difficult (Fetters & Troniuk, 2000). It has been suggested that prediction of motor outcome for less-severely compromised infants may require more than a single measure of motor performance (Fetters & Troniuk). Evaluation of performance over time (two or more assessments at different ages) may capture more accurately the dynamic processes involved in motor development improving the accuracy of predicting motor outcomes.

Stability and Continuity

When examining performance over time, such as is the case with development, it is useful to consider the concepts of stability and continuity. These concepts provide some clarity to the complex issues involved with examining performance at different ages.

Stability refers to the "preservation of individual differences on measures of a variable taken at two points in time . . . [while continuity refers to the] . . . preservation of structural relationships among variables, in the factor analytic sense (Wohlwill, 1980, p.362). An infant's gross motor performance would be considered stable if his or her ranked performance relative to a reference group were reasonably consistent across age. A variable such as gross motor performance would be considered continuous if many individuals retained reasonably consistent ranked performance over time and factor

analytic studies of item performance revealed similar factors associated with the variable at different ages.

Continuity becomes important when the examination of a variable at different ages requires the use of different means of measurement to be meaningful. For instance, the measurement of a child's ability to imitate a scribble is meaningful at 15 months but not at 10 years. Because it is possible to conceive of an underlying process that is present at different ages (e.g., visual motor integration), attempts are made to use test items that *appear* to be measuring the same underlying process at different stages of development (e.g., imitating a scribble, copying a complex design). Kagan (as cited by Wohlwill, 1980) has used the term *heterotypic continuity* to describe the relationship between two seemingly different variables, when there is some theoretical rationale for assuming there is a continuous connection or similar underlying process.

To provide confirmation of the continuous nature of the variable, factor analytic studies are recommended. A similar "structural relationship among variables" (Wohlwill, 1980, p. 362) at different ages would support the assumption of continuity for a specified construct over time.

Schneider (1993) discussed the issues of stability and continuity in relation to longitudinal studies of motor development and provides some guidance for researchers. He suggests that long term studies, especially those spanning several years and involving the use of different measurement instruments, may have serious limitations in their usefulness for assessing intra-individual change over time. However, short-term studies involving repeated use of the same measurement tool can provide meaningful information pertaining to developmental function (Schneider). Despite this, Schneider

does acknowledge that even within the same measurement instrument, "a variable may appear to be the same at various ages when in fact it is not" (p. 320). Careful theoretical consideration of the items used to measure a variable at different stages of development may be prudent.

Because the current study uses the same instrument over the period of one year, it meets the criteria suggested by Schneider (1993) for the meaningful evaluation of developmental function. However because factor analytic studies have not confirmed the continuity of the constructs examined by the instrument used in this study, this study will be mostly examining stability and not continuity.

Defining the Constructs within Motor Development

In response to concerns about unsubstantiated assumptions related to the continuity of motor development, Burton and Rodgerson (2001) have suggested the use of alternative terms to describe more accurately the concepts of skills, abilities and general motor ability. Their concerns include unsubstantiated theoretical and research support for continuous and stable constructs, inconsistent use of these terms by clinicians and widely accepted use of assessment tools that appear to provide measures of motor ability that may or may not be justified by statistical analysis (Burton & Rodgerson). The concepts of movement skills, movement skill sets, movement skill foundations and general motor ability are suggested.

Movement skills are defined as "a group or class of movements that have a similar movement form and function, which can be modified by practice or experience" (Burton & Rodgerson, 2001). These skills are developed in response to functional needs and limited by task demands and environmental constraints (e.g., reaching). *Movement skill*

sets are "categories or classifications of skills" (Burton & Rodgerson, p. 356) based on some criteria that may be defined by function (e.g., object manipulation), attributes *assumed* to be required for the tasks (e.g., visual motor integration) or environmental constraints (e.g., environment stable or changing). *Movement skill foundations* describe the traits of an individual that may influence movement skills (Burton & Rodgerson). This would include such factors as body composition, cognition, flexibility, muscle strength and endurance. The authors suggest these traits are similar to rate-limiters as described by Thelen et al. (1993) and that they are more strongly related to genetic influence than are movement skill sets, which appear to be more highly influenced by environmental influence. *General motor ability* as adopted from Schmidt and Lee is the "single trait of an individual that underlies the performance of all movement skills" (as cited by Burton & Rodgerson, p. 360). The authors argue that this concept be clarified despite the controversy regarding its existence, as it has not been either fully supported or refuted by research and is commonly inferred within the practice of assessing motor skills.

Although these terms are not used in this study, careful consideration was given to the principles underlying the arguments provided by Burton and Rodgerson (2001). The author also refrained from using the term *ability* which may imply generalized ability but instead used *performance* to refer to an infant's motor score and *domain* to refer to a specific skill set (e.g., fine motor or gross motor). These terms are understood clinically and may be less misleading.

Cognitive Development in Infancy

In contrast to the research in motor development, a substantial amount of research related to cognition has explored the issues of stability and continuity. Consistency of intellectual scoring has been demonstrated in children preschool age and older but the predictive validity of tests of early cognitive development on later intelligence is poor (Bornstein, 1989). This has resulted in two general views: either "there is no general intelligence factor in infancy . . ." (i.e., continuity of intelligence) or " . . . it is not stable, at least during the early part of the lifespan" (Bornstein, p.148). There are concerns that the tools used to measure cognitive development in infancy and childhood may not be sufficiently and exclusively measuring the constructs relevant to intelligence (heterotypic continuity). For instance, some items within these measures have been criticized for being more closely related to motor and affect than cognition (Bornstein, 1989).

It has been noted that stability of cognition is higher for infants with significant impairments (as was noted with prediction of motor performance for severely compromised infants). Aylward and Kenny (as cited in Spreen et al., 1995) reported that 45% of the variance of later intellectual outcome for infants with developmental quotients below 80 was explained by early testing. This has not been equally supported for infants with less severe delays. A large, longitudinal study of infants to age three revealed that 71% of infants considered cognitively *suspect* at 40 weeks tested normal at three years (Aylward, Gustafson, Verhulst & Colliver, 1987).

Variability in Intelligence

Concerns related to the stability and continuity of intelligence is not limited to infant studies. Moffit, Caspi, Harkness and Silva (1993) identified a "non-trivial minority

of children . . . [(13.4%), aged 7 to 13 years, who] . . .exhibited substantial changes in IQ" (p. 497) over a two-year period. Thorough examination of these changes revealed that they were reliable and beyond what would be expected with measurement error (Moffit et al.). The mean change between adjacent scores for these children was 16 IQ points, however when the amount of overall change was calculated (positive change minus negative change), the mean change for these children was only 5.3 IQ points. Clearly these children are demonstrating fluctuating scores rather than consistent changes in one direction despite the fact that some of the children's scores entered the "superior and retarded ranges at some test ages" (Moffit et al., p.485). The mean IQ score for these children, as a group did not differ from non-variable children at each age tested with the exception of age 13 when the variable children's average score was higher than the non-variable children.

Moffit et al. (1993) analyzed group differences between the variable and non-variable children in regards to "family context and individual differences" (p. 486) in an attempt to explain the variability noted with some children. Only a few significant differences were observed: highly variable children were more likely to be male (60%), perform poorly on a motor performance measure at five years and experience a greater number of residential changes (Moffit et al.). It was possible for the authors to identify significant life changes in some of the children's lives that coincided with significant changes in IQ score although the authors note that for every one of these children there were five others who had experienced the same life event without significant changes in IQ score.

Stability of Infant Motor Development

In a recent longitudinal study of typical infant motor development, the Baby Study, most infants exhibited instability in gross motor performance (94%) and/or fine motor performance (99%) over five assessment occasions from 9 months to 21 months (Darrah, Hodge, Magill-Evans, & Kembhavi, 2002). Instability was conservatively determined by considering the standard error of measurement for each occasion. If the 95% confidence intervals for at least one score did not overlap with any of the other assessment points, the infant was considered to have unstable development. These typically developing infants had extremely wide ranges of percentile scores within one year of development; the average difference between individual infants' highest and lowest percentile scores was 39 for both fine and gross motor skills ($SD = 14$) (Darrah, personal communication, February, 2002). One infant was noted to have highest and lowest scores spanning 81 percentile ranks. The authors explained the instability observed within a dynamic systems perspective: development is non-linear and may occur in a series of leaps and bounds. This study also highlighted the clinical implications of extreme variability in scoring. Specificity for screening infants is substantially jeopardized when 61% of typically developing infants have at least one score that would be considered suspicious within clinical practice settings.

Relevance to Clinical Practice

Understanding the reasons why typically developing infants obtain suspicious scores would assist clinicians to discriminate between infants in need of service and those who are not. If typically developing infants with suspicious scores were simply more variable than other typically developing infants (similar to the variability identified in the

Moffitt et al. study, 1993), subsequent testing (developmental monitoring) could be used to confirm an infant's needs. Perhaps suspicious scoring in typical development is the result of a *resource competition* between domains. For instance, it has been suggested that infants may experience a 'lag' in their speech development when they are learning to walk (Niemi, 2002), or that after infants learn to sit they can then concentrate on fine motor skill development. If suspicious scoring were the result of a competition between developmental domains, clinicians may be able to use domain profiles to determine whether an infant is in need of services. An examination of the motor skill development of typically developing infants with suspicious scores would provide insight into possible explanations for suspicious scoring.

Present Study

This study used secondary data analyses to examine the fine motor and gross motor developmental profiles of typically developing infants whom have scores that would be considered *suspect* given single occasion testing. These infants represent a substantial proportion of the typically developing infants who participated in the previous Baby Study. A number of analyses were used to explore possible reasons for suspicious scoring in typically developing infants. These infants as a group were compared to other typically developing infants on average motor performance as well as two measures of variability in scoring. Cluster analysis and visual analysis was used to examine profiles of motor development and relationships between the development of fine and gross motor skills. Finally, the relationship between motor domains was examined using correlational analyses and an examination of the corresponding changes in one domain during substantial changes in the other domain.

Specific Goals

1) Are infants with low scores demonstrating generally lower-than-average motor performance?

This analysis was used to confirm or refute the possibility that these infants as a group have underlying movement foundations that may be limiting their performance in a number of movement skills (although within the range of normal as these infants were considered to be typically developing). It was also possible that these infants were demonstrating lags and spurts that when averaged did not indicate overall lower motor performance. If these infants were demonstrating significantly lower scoring within the 'low-scoring' motor domain, it would be important to determine whether they were also demonstrating lower motor performance in the second motor domain (possibly suggesting similar underlying factors influencing both domains).

This question was addressed by:

- a) Determining if the infants' fine motor and gross motor scores over the five assessments were significantly lower than the comparison group.
- b) Describing the *cumulative change*, observed for these infants in the low-scoring motor domain

cumulative change = overall change in standard score
(sum of the positive and negative changes in standard scores between each assessment occasion, Moffit et al., 1993)

Cumulative change was used to determine the combined effect of changes in scoring over time, to reveal any overall increases or decreases in developmental ranking (and therefore developmental rate) during this time period. A positive cumulative change

score would be observed if there was an overall increase in developmental ranking, suggesting that infants with low scores were below average initially but then slowly caught-up. Negative cumulative change would be observed if there was an overall decrease in developmental ranking, suggesting that the infants' performance relative to their peers was decreasing. If the cumulative change were zero, this would indicate that the infants' ranked performance was neither increasing nor decreasing during this time period.

2) Does extreme variability in performance partially explain the low scores?

This analysis addressed the possibility that these infants as a group were more variable in their motor performance leading to occasional 'dips' into the below-average range, similar to the children in the Moffit et al., (1993) who demonstrated wide variations in IQ performance.

Variability was examined by considering the range of scoring observed (magnitude of variance in scoring) and the number of times there were significant changes in adjacent scores. This question was addressed by considering two different calculations:

- a) Determining if the two groups differ in regards to the range of scoring observed:

$$\text{range of scoring} = \frac{\text{highest score obtained} - \text{lowest score obtained}}{\text{number of scoring occasions}}$$

- b) Determining if the two groups differ in regards to the number of *large* (greater than one standard deviation) changes between adjacent scoring occasions.
- c) If higher variability was observed in either of the above calculations, variability in the second motor domain was also examined.

3) Is there an interaction between gross motor and fine motor skill development that may provide some explanation for low scores?

The correlation between gross and fine motor skills in the original Baby Study was low to moderate (.15 - .38) (Darrah et al., 2002). This was significantly lower than the correlation reported (.98) for the entire normative sample (birth to 83 months) for the assessment tool used (Peabody Developmental Motor Scales, Folio & Fewell, 1983). A low correlation would indicate there is neither a clearly consistent positive or negative relationship (correlation) between the skill developments observed in these motor domains at this age range. A low correlation would result if there were a combination of positive as well as negative correlations over a period of time. A negative correlation may occur if infants were *focusing* on skill development in one area at the expense of skill development in another area. This is similar to "resource competition", a term used by MacWhinney (2002) when discussing the possibility of a competing relationship between language development and motor skill development in infants.

This question was addressed by:

- a) Determining if the pattern of motor development in one motor domain was similar (i.e., parallel), contrary (i.e., competing profiles) or unrelated to the other within individual infants
- b) Determining if there was a significant correlation between gross and fine motor scores during the low scoring occasions.

A significant negative correlation would result if there was a clear relationship between the magnitude of low scores in one motor domain and the magnitude of high scores in the second motor domain (i.e., the lower the low score, the higher the high

score). It was anticipated however, that not *all* low scores would have resulted from the competing interaction of these two motor domains and the degree of influence may not be related to the level of scoring. Therefore, in the following analysis, only low scores with significantly higher prior scores were examined.

- c) Determining if there was an increase in standard scores in the second motor domain during time periods when there was a substantial decrease in standard scores in the low-scoring domain.

A substantial decline in ranked performance would indicate minimal progress or a slowing of development within a motor domain. If resource competition was suspected, it may be more accurate to identify the corresponding change in the second motor domain, when minimal skill development was observed in the first motor domain. An increase in the performance of an infant in one motor domain during periods of minimal development in the other motor domain would support a competing relationship between the developments in these domains.

Methods

Sampling

This study involved secondary analysis of data collected for 120 typically developing infants. These infants were recruited through the recruiting nurse at the Perinatal Research Centre – University of Alberta, infant and mother programs at public health clinics within the Capital Health Authority, and posters (see Appendix A) and pamphlets placed within the Edmonton area (Darrah, personal communication, February, 2002). Volunteer families were included in the study if their infant was considered at low-risk for developmental delay (i.e., birth date was close to the anticipated due date, no

reported medical conditions or disabilities, and parents had no concerns about the way their infant was developing) (see Appendix B for screening interview questions).

To ensure the infants continued to be typically developing at 23 months a two-stage screening process was used. The infants were initially screened with the Diagnostic Inventory for Screening Children Preschool Screen (DISC Preschool Screen) (Parker, Mainland & Amdur, 1998). Infants scoring in the suspicious range were then assessed using the complete Diagnostic Inventory for Screening Children (DISC) (Amdur, Mainland & Parker, 1998). Infants who did not pass the full screen were excluded from the study.

It was necessary to limit participants to families that spoke English due to the nature of the instruments used. Families therefore were included only if parents spoke English to their child and read English at a grade eight level. Also, the original researchers had anticipated that a volunteer study may attract families from higher socioeconomic status, therefore volunteers were recruited from communities within Edmonton that would increase the probability of including families with lower socioeconomic backgrounds (Darrah, personal communication, February, 2002).

Measure

The Peabody Developmental Motor Scale (PDMS) was used to assess the gross motor and fine motor skills of the sample (Folio & Fewell, 1983); the revised edition of the PDMS (Folio & Fewell, 2000) was not available at the time data collection began. The PDMS is a standardized, norm-referenced test for children ages birth to 83 months. The norms are based on a sample of 617 children stratified to reflect the US population by geographical region, race and gender.

Both fine and gross motor performance could be examined using this instrument by calculating scores within the fine motor (FM) and gross motor (GM) scales. The PDMS – Fine Motor Scale (PDMS-FM) consists of 112 items over 16 age levels. The PDMS – Gross Motor Scale (PDMS-GM) consists of 170 items over 17 age levels. Interrater reliability correlation coefficients for the gross motor scale and fine motor scale are .97 and .94 respectively for item-only scores and .99 each for scoring that includes basal scores (Folio & Fewell, 1983, pp. 109).

Performance on individual test items is based on a 3-point scale (absent, emerging or completed). Raw scores may be converted into percentile ranks, standard scores or age equivalent scores based on the chronological or adjusted age of the child. Standard scores as represented by Developmental Motor Quotients (DMQ) were used in this study. These scores can be interpreted similar to IQ scores ($M = 100$, $SD = 15$) and the difference between scores is theoretically more equal than that expected from percentile ranked scores. The PDMS has demonstrated a high degree of discriminative ability between the age ranges tested in the present study. All comparisons between adjacent ages are significantly different at the .001 level.

Concerns have been raised regarding the inconsistent representation of sub-skill areas at different ages (Hinderer, Richardson & Atwater, 1989). During the age range tested in this study, *grasping* and *hand use items* have greater representation in the earlier months while the older age groups have greater representation of items classified under *eye-hand coordination* and *manual dexterity*. Because factor analysis was not used in the development of these subscales, it is unclear how inconsistent representation of subscale

items impacts the ability of the PDMS to examine the same construct at different ages (heterotypic continuity).

Procedure

Twelve motor therapists (occupational therapists and physical therapists) received training on the administration of the PDMS until 80% item-by-item agreement was achieved (Darrah, personal communication, February, 2002). Assessments were planned within one week of the targeted ages (9, 11, 13, 16 and 21 months). At the initial assessment, families answered *general information* questions to obtain background information for data collection (Appendix C). At each subsequent visit therapists inquired about any illnesses or circumstances that may have affected an infant's performance (Appendix D). Intermittent tests of reliability were used to ensure reliability over time. Inter-rater reliability was .99 (Darrah et al., 2002).

Data Analyses

A combination of individual and group analyses were used to examine low scoring within the developmental profiles of typically developing infants. To identify differences in average motor performance and variability in scoring between infants with recurring low scores and other typically developing infants, *t*-tests and Chi-square analyses were used. To identify common patterns within the developmental trajectories of infants with recurring low scores, cluster analysis and visual analysis was used. Finally to explore the possibility of a competitive relationship between gross and fine motor development, correlation analysis and paired *t*-tests were used.

Ethical Considerations

Families who were involved in the original study were regularly informed regarding their rights. The majority of families considered for the original study were initially approached by third-party recruiters for their permission to be contacted or families contacted the researchers directly. These families were asked specific screening questions to ensure they met the inclusion and exclusion criteria (Appendix A). Families who met the screening criteria were then informed regarding the purpose of the study, what their commitment would entail (including a schedule of planned assessments, locations and procedures), the absence of risk for their family and their child, as well as the possible benefits available to the family (Appendix E). Families agreeing to participate in the study were then informed of their right to refuse to participate in the study at any time and assured that their infant's information would remain confidential (see consent form, Appendix F). Finally a non-biased third-party contact was made available for the families to provide an avenue for families to address any concerns they may have prior to or during the study.

An expedited review for the current study was obtained from the Health Ethics Review Board – University of Alberta (Appendix G). This is consistent with the information provided to parents indicating that any secondary analysis would require additional ethics approval (Appendix F).

Results

Study Design

This study was a retrospective, descriptive examination of longitudinally collected data. The significance level for Chi-square, correlation and Hotelling's T^2 analyses were

set at $p = .05$. The significance level for the remaining t -tests was $p = .007$ (.05 alpha with Bonferroni correction for seven comparisons).

Participants' Characteristics

The final analyses included data from 112 out of 120 infants recruited for the original Baby Study. Three infants received suspicious scores on the full DISC (Amur, Mainland & Parker, 1998) assessment at 23 months and were excluded because they did not meet the established criteria for typically developing infants. Four infants had missing data for one assessment occasion and one infant's data was excluded at the request of the family. The attrition rate for this study was low (7%) causing minimal threat to the internal validity of the study.

The sample included 52 girls (46%) and 60 boys (53.6%). Ethnic representation was as follows: 97 (87%) infants were Euro-Canadian, two (2%) were Chinese, two (2%) were South Asian and 11 (10%) had mixed ethnicity or were not represented by the above categories. The median income for families within the study was between \$50,000 and \$59,000, with responses ranging from less than \$20,000 to more than \$80,000. The median income for all families in Canada in the year 2000 was \$50,800 (Statistics Canada, 2002).

Thirty-three infants met the criteria for the low-scoring group (20 for the GM domain, 23 for the FM domain). Ten infants met the criteria for both domains. These 10 infants were excluded from one analysis and treated as a separate group in another, but otherwise grouped with the other low-scoring infants. Low scores occurred at all of assessment ages (see Table 1). Results of Hotelling's t -test, $F(2, 100) = .047, p = .954$, revealed no significant differences between the low-scoring group and the comparison

group on number of illnesses ($M = 1.80$, $SD = .23$; comparison group $M = 1.79$, $SD = .14$) and number of hospitalizations ($M = .30$, $SD = .12$; comparison group $M = .28$, $SD = .07$). This analysis included estimated scores for 11 infants with missing information for a single occasion (the mean of an infant's reported hospitalizations or illnesses was used to estimate missing data) and excluded 9 infants with two or more missing data. Chi-square analysis of the difference between groups on SES was not significant, $\chi^2(2, N = 103) = 3.172$, $p = .205$, (see Table 2); 9 infants were excluded due to missing data points. Chi-square analysis of gender also indicated the groups were not different, $\chi^2(1, N = 112) = .018$, $p = .894$.

Average Motor Performance (Research Question 1)

Infants in the low scoring groups have significantly lower average motor performance in the low-scoring domain relative to the comparison group (see Tables 3 and 4). The mean gross motor performance score for infants in the low gross motor group was a DMQ of 79.6 (ranging from 65.8 to 88.6), placing these infants in the low average range and significantly lower than the comparison group ($M = 99.6$), $t(97) = 13.086$, $p < .001$. The mean score was more than one standard deviation below the normative mean of the test ($M = 100$, $SD = 15$). Infants with low fine motor scores had a mean fine motor DMQ score of 86.8 (ranging from 82.6 to 94.0) which was significantly lower than the comparison group ($M = 97.5$), $t(58.014) = 12.053$, $p < .001$. Although this result could have been expected given that group membership was based on an infant's performance on two out of five scoring occasions, this analysis did confirm that infants with recurring low scores do not have similarly extreme high scores, resulting in an insignificant difference in average scoring between the two groups.

Performance in the second motor domain was significantly lower than the comparison group for infants with low fine motor scores, $t(25.580) = 4.428, p < .001$ (see Table 4) but not for infants with low gross motor scores, $t(22.485) = 2.412, p = .024$ (see Table 3). Because there were concerns that a significantly lower second domain score might be influenced by the 10 infants who had multiple low-scoring occasions in both domains, the analysis for the infants with low fine motor scores was redone excluding these infants. The results indicated that infants who only scored low in the fine motor domain did not have lower average gross motor performance when compared to the comparison group, $t(90) = 1.628, p = .107$ (see Table 4).

Cumulative change scores (sum of the positive and negative changes in standard scores between each assessment occasion) were calculated to reveal any overall increases or decreases in developmental ranking during this developmental period for both low scoring infants and infants in the comparison group. Average cumulative change in FM for infants in the low-scoring FM group was similar to the comparison group (see Table 5) however average cumulative change in GM for the low-scoring GM group was much higher than the comparison group. With further examination of individual profiles it was noted that 13 out of 20 infants in the low-scoring GM group (65%) demonstrated a cumulative increase in standard score more than 1 *SD* or 15 DMQ between the ages of 9 months and 21 months.

Variability in Motor Performance (Research Question 2)

Variability in motor performance as measured by the range of scoring over the five assessment occasions (highest score – lowest score) was not significantly different between the low scoring group and comparison group (see Table 6). Infants with

recurring low gross motor scores do not have scores that span a larger range, $t(97) = -2.088, p = .039$, nor do infants with low fine motor scores, $t(100) = -1.774, p = .079$. It is important to note, however, that a number of scores in the low-scoring group were calculated as a DMQ of 65 despite large differences in raw scores (65 is the lowest DMQ score listed on the conversion chart in the PDMS manual; Folio & Fewell, 1983). For example, one infant (Baby 76) had raw scores of 82, 85 and 103 in the gross motor scale at 9, 11 and 13 months; when converted all scores were equal to a DMQ of 65. This 'floor effect' may have limited the overall range of scoring for these infants. No similar 'ceiling effect' limited the range of scoring for the comparison group.

There was an association between the number of large changes in adjacent assessment occasions, and group membership for the infants with low GM scores (see Table 7) but not for the infants with low FM scores, $\chi^2(2, n = 102) = 3.962, p = .138$ (see Table 8). Infants with low gross motor scores had a greater number of large changes in DMQ scores than infants in the comparison group.

Given the significantly higher variability (number of large changes) identified in the group of infants with low gross motor scores, variability in the second domain was also examined (see Table 9). There was no significant difference between infants with low gross motor scores and infants in the comparison group in the number of large adjacent changes in fine motor performance, $\chi^2(2, n = 99) = 2.437, p = .296$.

Developmental Trajectories for Gross and Fine Motor Performance (related to Research Question 3)

To examine the relationship between GM and FM developmental trajectories for infants with recurring low scores, a combination of hierarchical and partitioning cluster

analyses were used. Ward's cluster analysis (squared Euclidean distance, within groups linkage) was used initially to determine the most appropriate number of clusters within each low scoring group. K-means (partitioning) cluster analysis was then used to determine group membership. Unlike hierarchical analysis, partitioning allows case assignment to be recalculated each time cases change groups ensuring all cases belong to the group most similar to its variable combination (Jobson, 1992).

Within the low-scoring GM group, it was determined that four clusters provided the most stable clustering solution. Using partitioning analysis, group membership was as follows: Group 1 ($n = 9$; 45% of the group) identified infants with GM scoring patterns that are initially variable but then more stable at 16 and 21 months (see Figure 1a). All infants within this cluster have extremely low 9-month scores (more than 2 *SD* below the mean) with 16- and 21-month scores within 1 *SD* of the mean for the PDMS (with the exception of two scores of 83 and 84 for two different infants). Five of these infants had distinct patterns of low 9- and 13-month scores (< 2 *SD*) interrupted by significantly higher 11-month scores (non-overlapping confidence intervals).

GM group 2 identified infants ($n = 5$; 25% of group) with profiles of low initial scores followed by a general increase in ranked performance (some gradual and some abrupt) with stabilization (see Figure 1b). Confidence intervals were used to determine whether adjacent scoring changes were abrupt or gradual. All infants had their lowest scores at 9 months and peak scores at either 13 or 16 months. All 21-month scores fell within 1 *SD* (> 85 DMQ) of the mean for the PDMS with the exception of one infant with a DMQ of 84. Three of these infants also met the criteria for the low scoring fine motor group.

Group 3 included only two infants (10% of group). These infants had profiles of high 9-month scores, significantly lower 11- and 13-month scores and rebounding 16- and 21-month scores (see Figure 1c).

Group 4 included four infants (20% of group) with scores that fell below 85 on four or more occasions out of five (see Figure 1d). Despite the consistency of low scoring for these infants, it is important to remind the reader that all infants within this study met pre-established criteria that classified them as typically developing using information gathered prior to and following the study.

Hierarchical cluster analysis determined that four was also the most appropriate number of clusters for infants within the low-scoring FM group. Partitioning analysis was then used to sort infant profiles into four clusters; however, with thorough visual inspection, it was not possible to identify clinically meaningful distinguishing features of the groups (e.g., a few profiles that appeared to be quite similar were sorted into different clusters; see Figure 2). For this reason, cluster groupings for infants in the low-scoring FM group were not described.

Cluster analysis was also used in the original Baby Study. It is interesting to note that all infants considered to be low-scoring in regards to gross motor performance in the present study clustered into one group within the larger sample of typically developing infants (Darrah, personal communication, August, 2002). Clearly these infants had scoring levels and/or developmental patterns that caused them to be distinctly different from other typically developing infants. Cluster analysis for infants' fine motor profiles is not yet available. The infants considered to be low scoring in their fine motor performance (as per the present study) may be similarly distinct from their peers as are

infants with low gross motor performance. Further separation of this group into distinct profiles may not be possible (hence clusters are not clearly distinguishable).

Relationship Between Gross and Fine Motor Performance (Research Question 3)

Three types of analyses were used to examine the relationship between GM and FM performance. This included visual analysis of pairs of developmental trajectories, correlation analyses and an examination of large changes in adjacent scoring that might provide an indication of resource competition.

Visual analysis of second domain profiles was performed only for infants in the low gross motor group; as discussed above, it was not possible to clearly describe profile groups within the group of infants with low fine motor scores. No consistent relationship between profiles of FM and GM development was observed. Even among infants with very similar GM profiles, FM trajectories were quite dissimilar. For instance, six infants within cluster group 1 had nearly identical GM developmental trajectories but very different corresponding FM profiles. Two infants had FM profiles that were parallel to their corresponding GM profiles including some abrupt adjacent changes in scoring (Figure 3a), two had changes in adjacent scores that were in the opposite direction to gross motor changes (Figure 3b), one infant had a combination of changes parallel and opposite to gross motor changes (Figure 3c) and one infant had stable fine motor scoring (all scores had overlapping confidence intervals) despite the variability observed in GM development (Figure 3d). Other cluster groups had similarly inconsistent FM profiles.

The relationship between fine and gross motor scoring during low scoring occasions was examined using Pearson product-moment correlation coefficients. Sixty-one occasions of low GM scoring was observed within the low GM group and 60

occasions of low FM scoring was observed within the low FM group. The correlation was not significant during low GM occasions ($n = 61$; $r = -.093$; $p = .237$) or during low FM occasions ($n = 60$; $r = .138$; $p = .147$). Because individual infants contributed more than one data point for this analysis, the analysis was re-run with one randomly selected data point per infant; the resulting correlations were also not significant.

There were also concerns that this correlation might not accurately represent the relationship between gross and fine motor scores because of the inherent limitation in the range of scoring within the low scoring domain. In an attempt to more accurately capture this relationship, the correlation between FM and GM was calculated for each assessment occasion within the entire low-scoring infant group (Table 10). All correlations were not significant with the exception of the 9-month assessment, $r = -.386$; $p = .027$. This negative correlation suggests there is a tendency for higher scores in one domain to be associated with lower scores in the other domain. However, this degree of correlation is considered to be only fair (Colton, as cited by Portney & Watkins, 1993). Finally, the correlation between FM and GM was calculated for the ten infants meeting the low scoring criteria in both domains; again no significant correlations were identified (Table 10) which is not surprising given the small sample size. However, the overall magnitude of the correlations was low (ranging from $r = -.305$ to $.348$).

Occasions during which there was a large negative change in ranked performance preceding low scores (indicating a substantial lag in development) were examined to determine if the slowing of developmental rate in one domain was associated with increasing developmental rate in the other domain. Results indicated that the corresponding change in the second motor domain was not significant for both low GM,

$t(20) = 2.371, p = .028$, and low FM scoring occasions, $t(18) = 1.596, p = .128$ (see Table 11).

Discussion

This study used the analysis of longitudinally collected data to answer the question of why typically developing infants obtain motor performance scores that would be considered suspicious in clinical settings. Three possible reasons were examined: 1) infants with low scores have overall motor performance in the lower tail of the distribution for typically developing infants providing the opportunity for motor scores below the 16th percentile, 2) infants with low scores have more variable motor performance than other typically developing infants resulting in both extremely high and extremely low scores, 3) the interaction between gross and fine motor skill development could be an example of 'resource competition', illustrated by the observation of low scores in one domain during high scores in the other. Results of this study provide support for the first explanation, mixed results for the second explanation, and no support for the third.

Typically developing infants with motor scores in the suspicious range had lower mean motor performance when their scores were averaged over time which is not surprising given that infants had to have two or more low performance scores to be included in the low scoring group. What was more surprising was the range of their scores which was limited to the low-average range. The average gross motor score for all infants (across all assessment occasions) in the low gross motor group was a DMQ of 79.6. This mean score is more than one standard deviation below the normative mean of 100 for the standardized measure used in this study ($SD = 15$) (Folio & Fewell, 1983).

The highest single score for an infant in this group was a DMQ of 99. Infants with low fine motor scores had a mean fine motor DMQ score of 86.8 and the highest single score for an infant in this group was 105. These scores place the infants in the low average range particularly in the area of gross motor skills.

What, if any, are the implications of having mean scores in the low-average range? Can mean motor performance over a number of occasions be assumed to provide a better indicator of true *underlying ability* than scores from a single testing occasion? Will these infants continue to have occasional dips into the suspicious range of scoring when they are followed further? In order to provide definitive answers to these questions, long term follow up of the children in this sample is needed. Long-term follow up would indicate if scores in the low-average range are predictive of future low average motor functioning that is still within the range of typical development. It would also indicate if there were any associated challenges with functional tasks required in the course of a child's life.

In the absence of long-term follow up data, information from the developmental profiles may provide some clues for understanding the implications of having a mean score in the low-average range. For the gross motor domain, the mean cumulative change for infants with low gross motor scores from 9 months to 21 months was a DMQ of +13.75; in effect mean scores increased almost 1 SD over the period of one year. This trend was particularly apparent for infants with profiles in cluster groupings 1 and 2. For the nine infants in Group 1 and the five infants in Group 2, the instances of low scoring occurred early in the assessment period and were followed by scores in the average range. For these children, one would not expect instances of suspicious scores in future

assessments unless there were major changes in the factors influencing future gross motor performance (tasks, the environment, or intrinsic characteristics). However, the four infants in Group 4, who had several scores below a DMQ of 85, might reasonably be expected to have future occasions of suspicious scores if intrinsic and external factors influencing motor skill development remained much the same in their lives (and these factors continued to be important for gross motor skills developed at later ages). Cluster analysis did not provide the same clear hints for infants in the one remaining gross motor cluster or for expected performance in the fine motor domain.

The 10 infants who had scores in the suspicious range on two or more occasions in both gross and fine motor domains must also be considered when interpreting the results of the low average mean scores. These infants appear to differ from the rest of the low scoring group as low scores in one domain appeared to be associated with low scores in the other domain (not observed for the other 23 infants in the low scoring group). However, the gross and fine motor scores were not significantly correlated for this subgroup of children (correlations range from $r = -.305$ to $.348$ for ages tested) and there did not appear to be one clear pattern for the scoring profiles. Gross motor profiles for these infants were varied: three infants clustered in each of groups 1, 2 and 4 and one infant clustered in group 3. Fine motor profiles were also quite dissimilar. The long-term implications of multiple low scores in both domains are not known but certainly these infants' scores would concern clinicians and raise questions regarding the influence of similar underlying factors on both developmental domains.

From a dynamic systems perspective, knowing a child's average scores at one period in time would not be assumed to predict future performance. The nature of the

interaction of the environment, the task, and child characteristics would not remain the same in the future as it was in infancy. The interaction of these factors would influence motor performance and motor skill development which in turn would affect the child's characteristics, environment and the activities chosen, again influencing motor performance and skill development. The assumption that a child's performance ranking on motor skills at one time predicts future motor ability places a high degree of emphasis on the child's present characteristics disregarding the influence of future affordances (factors contributing to skill development) and constraints (factors that are obstacles to skill development). Prediction may be especially poor for infants as many of the underlying mechanisms that influence motor skill have not fully developed. As Piper (1993) suggests, prediction from infancy may be based on inaccurate assumptions that mild or moderate motor impairment is constant; infants with delays may not always become children with delays and some motor delays may not be discernable at an early age.

The second explanation for low scores, namely increased variability, received some mixed support. Infants with low gross motor scores were more variable when the number of significant changes in adjacent scores was considered. In fact one quarter of infants with low *gross motor* scores had three or more large adjacent changes (>15 DMQ or >1 *SD* on the PDMS) in scoring in contrast to none of the infants in the comparison group; 65% of the comparison group had no large changes in scoring as compared to the 30% of those with low gross motor scores. However infants with low fine motor scores did not have a greater number of large changes in adjacent scores than other typically developing infants. Also, infants with low motor scores (gross or fine motor) were not

significantly different than other typically developing infants in regards to their range of scoring. As indicated previously, the true nature of the variability may not have been detected due to the limitation in the range of low scores as the scores could not drop below a DMQ of 65. Thus, greater variability cannot be completely ruled out as a possible explanation for occasional suspicious scores.

Others have looked at explanations for variability in performance. Coryell, Provost, Wilhelm and Campbell (1989) suggested three possible reasons for the variability they observed in the longitudinal performance of 15 low-risk and 8 high-risk infants on the Bayley Motor Scale (Bayley, 1969). Their explanations included variability due to the measurement tool, the specific subjects in their study or "the nature of infant development" (Coryell et al., 1989, p. 837). Variability could be observed simply because of the method of calculating scores if an infant were assessed at inconsistent time points within the normative age groupings provided in the assessment tool. A difference of 39 DMQ in an infant's standard score would be observed if an infant's gross motor skills were tested one day prior to turning 10 months of age and then one day later (a different conversion table is used for infants 8-9 months than for infants 10-11 months). Because this study used assessment ages that purposely fell in the middle of the normative age groupings provided by the PDMS, variability due to the measurement tool was minimized. Coryell et al. reported that a number of the infants in their study may have been recovering from perinatal insult contributing to increased variability (initial low scores followed by higher scoring). Because there were no high-risk infants in the present study and precautions were taken to ensure infants were typically developing, these effects should have been minimized. Also the infant motor profiles did not follow a

consistent motor profile, suggesting that individual performance, not the assessment tool, influenced variability. The variability observed within this and the previous Baby study was likely reflective of the nature of typical infant motor development.

This is consistent with dynamic systems theory. According to dynamic systems theory, motor milestones are qualitatively new skills that appear discontinuously as new forms of behavior (Thelen et al., 1993). It has been demonstrated that different, typically developing infants use different means of acquiring the same motor skill, such as reaching (Thelen et al., 1993), based on each individual's unique combination of affordances and constraints relevant to the development of the skill. Assuming infants develop other motor skills in the same self-discovery process as has been suggested for reaching, one would not expect motor performance, when measured using motor skills, to develop in a linear fashion but rather in a series of spurts and plateaus as different "heterogeneous components [are] assembled" (Thelen et al., 1993, p. 1059) in the development of different motor skills.

Although the variability identified in this and the previous Baby study was likely reflective of the nature of infant development, significant differences were identified in the degree of variability observed in infants with low gross motor scores compared to other typically developing infants. Possible explanations might include differences in infant temperament or learning style or specific combinations of affordances and constraints provided each infant. Temperament has been noted to be an influence in the development of other skills such as language. Bloom (1993) suggested that differences in infant temperament may explain why some infants learned words early and other did not. Early word learners "were, in general, more stable in their profiles of emotionality than

were the later word learners" (Bloom, 1993, p. 182). Thelen et al. (1993) noted temperament differences among four typically developing infants as they were learning to reach. A few infants were very motorically active; early attempts at reaching were very crude subsequently followed by gradually increasing control of these large movements in order to successfully reach an object. One infant (Hannah) was less motorically active but "visually alert" (Thelen et al., p. 1080); her first attempts at reaching occurred later in development than the other infants but when attempts were made these were "quite smooth and mature-looking" (p. 1081). If the stages of reaching were assessed for these infants, it may appear that Hannah was more variable in her skill development than the other infants. If it can be assumed that temperament has an influence on the development of other motor skills, equally influencing gross and fine motor skill development, higher variability would be observed in both domains. This was not evident in this study. Infants with low gross motor scores were more variable (in regards to the number of large adjacent changes in scoring) in gross motor scoring but not in fine motor scoring.

The other possibility is that infants with variable scoring have specific combinations of affordances, constraints and rate-limiting factors that influence the development of different motor skills in different ways, creating profiles of spurts and plateaus in motor development. Coryell et al. (1989) suggested that variability in infant motor performance over time may be related to environmental factors, variability in the rate of development of certain underlying mechanisms or a predilection infants may have for certain activities. Each infant's individual circumstances (intrinsic and external factors) may influence different motor skills in different and unique ways. An infant learning to crawl in an environment without stairs may not learn how to climb up and

down stairs at the same age as other infants but other developmental skills such as stacking blocks would not necessarily be affected by this circumstance. Other differences such as the rate of development of underlying mechanisms (e.g., balance) would influence some motor skills more than others. Finally infants with a 'predilection' for certain activities can be expected to score higher on those activities.

Because developmental tests must use age discriminating items at each age range tested, differences in the above examples of environment, rates of development and infant fondness for certain activities could lead to variability in scoring over time. What is uncertain however, is why certain infants are much more variable in their scoring than other infants. It is interesting to note however, that there were a number of infants with substantial variability in scoring who demonstrated very similar profiles of plateaus and spurts in their gross motor scores over time. Further analysis of item specific scoring for these infants may lead to a better understanding of the course of gross motor development for this notable minority of typically developing infants perhaps leading to a better clinical understanding of why some typically developing infants are more variable and subsequently why some of these infants obtain suspicious gross motor scores.

Besides the increased variability identified in the number of large changes in adjacent scores for infants with low gross motor scores, this study provides little support for increased variability as the best explanation for low scores. It is noteworthy however that infants with low motor scores were *no less variable* than other typically developing infants in any of the above analyses. The combination of lower mean motor performance with typical variability in performance creates substantial opportunity for infants to obtain suspicious scores.

The final possible explanation for suspicious scores required examination of the influence of second motor domain performance on low fine or gross motor scores. This was done in three different ways. Pairs of gross and fine motor developmental profiles were examined (visual analysis) for infants with low gross motor scores, the correlation between scores was calculated at each age tested, and the corresponding change in second domain performance was examined during periods of declining ranked performance in each motor domain. A consistent pattern representing the relationship between pairs of motor profiles was not evident. Some infants' scoring profiles demonstrated parallel relationships between the rates of change in gross and fine motor performance, others demonstrated opposing relationships (as one domain increases the other decreases and vice versa) and still others demonstrated profiles that were neither consistently parallel nor opposing. Correlations between domains were insignificant for all ages (with the exception of 9 months, for which only a fair negative relationship was identified). Finally there was no indication that an increase in ranked performance in one domain occurred during substantial lag in the skill development of the opposite domain. Clearly the patterns of change (or rates of development) between these domains for typically developing infants with low scores, as examined in this study, were unrelated.

The distinction between gross and fine motor performance in infancy has also been reported in other infant studies. Folio and Fewell (1983) reported very different correlations between the Bayley Mental Scale and the FM (.78) and GM (-.03) scales of the PDMS (Bayley, 1969; Folio & Fewell, 1983). Palisano (1986) identified a similar discrepancy between correlations of the scales with the Bayley Motor Scale (.78 - .95 with GM scale; .20 -.40 with FM scale). Since the Bayley Motor Scale contains no fine

motor items beyond the 8-9 month age, Palisano concluded that "performance on gross motor items is not related strongly to performance on fine motor items" (p. 1718).

Evidence of competing relationships (i.e., resource competition) between different developing domains remains scarce despite commonly held assumptions (e.g., late walkers are early talkers and vice versa). A number of studies have acknowledged a generally poor relationship between the development of different domains in infant development (such as those described previously), with the exception of some instances where a functional relationship was presumed to exist (e.g., development of voluntary grasp may be related to initial attempts to stand/walk because grasp is necessary for these initial attempts; Touwen, 1976). In a study by Bloom (1993) two measures of motor maturation (age of walking and block building) were found to be unrelated to the development of language, affect expression or play with objects (cognition). Bates (1979) also found no correlation between the development of major motor milestones and language. Insignificant relationships between domains may provide sufficient explanation for the scarcity of evidence to support resource competition. If the relationship between domains were poor, there may be little reason to suspect the same resources are being accessed eliminating the need to compete for resources. However if it is assumed that an infant's *attention* is in competition during the development of various skill areas, the timeline for observing the effects of competition may need to be smaller than that observed in this study. As noted by Bloom (2002), competition between language and motor skill development may be observed in *real* time (e.g., infants may not be saying words *while* trying to stack one inch cubes or taking their first steps).

In conclusion, it is apparent that low motor scores in typically developing infants are associated with lower-average motor performance. Lower-average motor performance paired with the degree of variability observed in typical infant motor development appears to provide sufficient opportunity for infants with lower average motor ability to obtain suspicious motor scores. Further research is needed to determine whether longitudinal profiles of low average motor scoring continue into childhood and if there are any functional implications for children with these profiles. This study has provided some limited evidence that infants with suspiciously low gross motor scores were more variable in scoring over time when compared to other typically developing infants. Higher rates of variability may be related to specific combinations of affordances and constraints for each infant. The consistency of certain variable gross motor developmental profiles warrants further investigation. Finally the interaction between the development of gross motor and fine motor domains does not appear to be a factor influencing suspicious scoring in typically developing infants. Fine and gross motor developmental profiles appear to be unrelated in typical infant motor development.

Relevance to Clinical Practice

As reported in the Baby Study, suspicious motor performance scores occur with substantial frequency within typical infant motor development (Darrah et al., 2002). Despite the careful selection of infants at low risk for developmental disabilities, at any one of the ages when the infants were assessed, 7 to 23% obtained scores that would have been considered suspect. Clinicians need to be continually vigilant in their interpretation of motor assessment results when screening infants. Developmental surveillance or

monitoring of development has been recommended as a means to more accurately predict motor performance at later ages (Coryell et al., 1989; Darrah et al., 2002; Palisano, 1986).

This study has supported the conclusion that typically developing infants with low motor scores have lower average motor performance and are equally, if not more, variable in their motor performance. Given the above conclusions, follow-up assessment of typically developing infants with suspicious scores has a reasonable chance of being higher. Because consistent low scoring has been commonly associated with impairment, discriminating between infants with and without motor impairment should be possible through developmental surveillance. However, further studies are needed to identify if average motor performance and/or variability in development can be used to sufficiently discriminate between infants with typical development and those with atypical development. Developmental profiles may provide more accurate prediction of motor outcome. Clinically useful guidelines to identify atypical developmental profiles would then need to be developed.

It is also clinically relevant to acknowledge the relationship between gross and fine motor performance in typical infant development. First, low mean performance in one domain does not predict low mean performance in the second domain for typically developing infants. Clinicians should continue to consider both domains separately when assessing motor performance in infancy. Secondly, it does not appear that resource competition between domains can be used to explain low scoring in either domain. Infants demonstrating substantial decline in ranked performance in one domain are not showing an opposite increase in ranked performance in the other domain.

Finally careful consideration should be given to the use of terms that convey *underlying ability* has been measured when norm-referenced tests of motor performance in infancy are used. Conscious attention to the many factors that are now known to influence infant performance (e.g., biomechanical properties of the infant, state of the infant) as well as the discontinuous nature of motor development in infancy should alert clinicians to the possible sources of variance or error in the interpretation of performance measures. Alternative terms such as *motor performance* may help to prevent unintentional inferences regarding the predictive ability of norm-referenced developmental measures until such time as more accurate prediction of motor outcomes can be obtained.

Limitations

Despite careful consideration of inclusion and exclusion criteria to select typically developing infants, the only way to confirm these infants are typically developing is to re-examine their skills in later childhood. It is possible that some of the infants within this study will develop mild or moderate motor impairment (i.e., developmental coordination disorder) in later childhood, as the incidence is approximately 4-5% of the population (Henderson & Hall, 1982; Missuna, 1994). Follow up of these infants, as planned by the authors of the Baby Study, will confirm motor outcomes and allow retrospective examination of infant scoring profiles to identify if there are any early indicators for infants with poor motor outcomes and conversely what profiles that appeared suspicious in infancy resulted in typical childhood motor development. Follow up will also identify if and when variability in motor performance becomes less of a factor in typical

development and when one could reasonably expect to accurately classify an individual as typically developing.

Mean scores obtained for the sample in this study were consistently below the mean reported in the PDMS despite the strategic inclusion of only low-risk infants. Mean GM and FM scores ranged from 93 to 98 DMQ for the age ranges tested in this study (mean PDMS scores are 100 DMQ). This discrepancy, although small, may be due to one of the following explanations. The PDMS normative sample may not be reflective of this sample as Canadian children were not included in the 1983 norms. Unclear scoring criteria may have caused discrepancy in scoring as it was necessary for the Baby Study therapists to adopt certain conventions to consistently score certain items; these conventions may or may not have not been consistent with scoring practices used with the PDMS normative sample. Finally it is possible that this sample of infants may not be representative of typically developing infants although this is a remote possibility given the inclusion and exclusion criteria used in the Baby Study. Lower mean scoring for this sample may have affected the number of infants that were identified as having suspicious motor scores.

Future Directions for Research

Future research is needed to provide answers to the following questions related to typical motor development: Is low-average mean motor performance in infancy predictive of low-average motor performance in childhood? Is substantial variability in infancy predictive of future variability? When does variability become less of a factor in motor development? Are specific motor performance profiles in infancy useful in the predicting typical (and possibly atypical) motor outcomes? What are the motor outcomes

in childhood for infants with low motor performance in both fine and gross motor domains?

Due to the efforts of the research team for the Baby Study, continued follow up of the infants from this and the previous Baby Study will occur from 4 ½ to 7 years of age (Darrah et al., 2002). The cumulative data made available from combining the Baby and child studies will provide an opportunity to examine some of the above research questions.

Additional research related to item specific scoring would also be useful to further understand the rate-limiting factors that occur in typical development. A number of infants with low gross motor scores had very similar variable gross motor profiles. If item specific scoring indicates these infants achieved specific motor skills in the same order and/or timeline, it may be possible to tease out similar rate limiting factors influencing motor skill development. Consistent with the dynamic systems theory, motor skills may be *discovered* as individuals seek means to accomplish functional tasks but patterns of motor skill development may be similar among individuals with relatively similar affordances and constraints. Identification of these patterns may contribute to further accuracy in predicting motor outcomes from infancy.

Additional research is also needed to examine the motor development of infants with substantial risk for developmental delay. Are high-risk infants or infants with identified mild to moderate developmental delay any less variable than typically developing infants? Is the frequency of suspicious scoring significantly higher than that observed in typical development? What are the motor development profiles for those infants? Can motor profiles be used to predict transient versus persistent motor delay?

Finally research is needed to confirm the results obtained in this study.

Examination of motor development using other motor performance measures would confirm these results were not a product of the measurement tool but rather a function of development. Further study of infant motor development in other populations (e.g., Americans for which the PDMS was normed) would also substantiate the frequency of low scoring observed in typical development.

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Table 1

Percentage of infants with low scores^a at each age

Age	Groups					
	Low scoring		Comparison		Total Sample	
	(n = 33)		(n = 79)		(n = 112)	
	GM	FM	GM	FM	GM	FM
9 months	58%	30%	9%	4%	23%	12%
11 months	45%	27%	5%	3%	17%	10%
13 months	48%	36%	1%	6%	15%	15%
16 months	21%	45%	1%	6%	7%	18%
21 months	21%	52%	3%	8%	8%	23%

Note. GM = gross motor skills; FM = fine motor skills.

^a Peabody Developmental Motor Quotient scores below 1 *SD*.

Table 2

Socioeconomic status of the low scoring and comparison group

Group	SES			Total
	< 29,000 ^a	30,000 – 69,000	> 70,000	
Low scoring	6 (19%)	14 (45%)	11 (35%)	31
Comparison	6 (8%)	43 (60%)	23 (32%)	72
Total	12 (12%)	57 (55%)	34 (33%)	103 ^b

^aUrban families of three living in large Canadian cities with incomes of less than \$28,560 per year are considered to be living below the poverty line (Canadian Council on Social Development, 2000).

^b9 infants had missing data for SES.

Table 3

Mean performance^a of infants with low gross motor scores and infants in the comparison group

	Gross motor [*]	Fine motor	Fine motor ^b
Low GM scoring group			
<i>M</i> (<i>SD</i>)	79.60 (6.74)	92.59 (8.65)	99.30 (7.23)
Range of <i>M</i>	65.8 – 88.6	82.6 – 109.2	87.4 – 109.2
	(<i>n</i> = 20)	(<i>n</i> = 20)	(<i>n</i> = 10)
Comparison group			
<i>M</i> (<i>SD</i>)	99.60 (5.94)	97.46 (5.13)	97.46 (5.13)
Range of <i>M</i>	86.0 – 113.8	86.4 – 107.8	86.4 – 107.8
	(<i>n</i> = 79)	(<i>n</i> = 79)	(<i>n</i> = 79)

Note. GM = gross motor skills.

^aaverage of the 5 scores for Peabody Developmental Motor Quotient, *M* = 100, *SD* = 15.

^bre-analysis excluding infants also meeting the criteria for the low-scoring fine motor group.

^{*}*p* < .001 (one-tailed *t*-test); equal variances

Table 4

Mean performance^a of infants with low fine motor scores and infants in the comparison group

	Fine motor*	Gross motor*	Gross motor ^b
Low FM scoring group			
<i>M (SD)</i>	86.83 (3.20)	88.68 (11.39)	96.71 (5.86)
Range of <i>M</i>	82.6 – 94.0	65.8 – 107.4	87.6 – 107.4
	(<i>n</i> = 23)	(<i>n</i> = 23)	(<i>n</i> = 13)
Comparison group			
<i>M (SD)</i>	97.46 (5.13)	99.60 (5.94)	99.60 (5.94)
Range of <i>M</i>	86.4 – 107.8	86.0 – 113.8	86.0 – 113.8
	(<i>n</i> = 79)	(<i>n</i> = 79)	(<i>n</i> = 79)

Note. FM = fine motor skills.

^aaverage of the 5 scores for Peabody Developmental Motor Quotient, *M* = 100, *SD* = 15.

^bre-analysis excluding infants also meeting the criteria for the low-scoring gross motor group.

**p* < .001 (one-tailed *t*-test); unequal variances.

Table 5

Cumulative change^a observed within the low scoring domain

	Gross motor ^b	Fine motor
	<i>M (SD)</i>	<i>M (SD)</i>
Low GM scoring group (<i>n</i> = 20)	+13.75(11.85)	-
Low scoring FM (<i>n</i> = 23)	-	-3.91(11.61)
Comparison Group (<i>n</i> = 79)	-2.41(11.52)	-3.42(14.78)

Note. GM = gross motor; FM = fine motor.

^aCumulative change scores are the sum of the positive and negative changes in scores over the 5 assessment occasions.

^bPeabody Developmental Motor Quotient scores, *SD* = 15.

Table 6

Range of motor scores^a for infants in the low-scoring groups and those in the comparison group

Group	Range of GM scores	Range of FM scores
	<i>M (SD)</i>	<i>M (SD)</i>
Low GM scoring group	22.95 (8.61) (<i>n</i> = 20)	-
Low FM scoring group	-	20.83 (5.78) (<i>n</i> = 23)
Comparison	18.68 (8.05) (<i>n</i> = 79)	17.92 (7.19) (<i>n</i> = 79)

Note. GM = gross motor; FM = fine motor.

^aPeabody Developmental Motor Quotient scores, *SD*=15; calculated by subtracting the lowest score obtained from the highest score obtained.

Table 7

Number of large adjacent changes^a in gross motor scores for infants in the low scoring gross motor group and those in the comparison group

Group	Number of large DMQ changes (>15) [*]				Total
	0	1	2	3+	
Low scoring GM	6 (30%)	5 (25%)	4 (20%)	5 (25%)	20
Comparison	51 (65%)	20 (25%)	8 (10%)	0	79
Total	57	25	12	5	99

Note. GM = gross motor.

^aDefined as >15 Developmental Motor Quotient (DMQ) points (equal to 1 *SD* on the Peabody).

^{*} $p < .001$; $\chi^2 (3, n = 99) = 24.344$.

Table 8

Number of large adjacent changes^a in fine motor scores for infants with low fine motor scores and those in the comparison group

Group	Number of large DMQ changes				Total
	0	1	2	3+	
Low scoring FM	9 (39%)	10 (43%)	4 (17%)	0	23
Comparison	48 (61%)	25 (32%)	6 (8%)	0	79
Total	57	35	10	0	102

Note. FM = fine motor.

^aDefined as >15 Developmental Motor Quotient (DMQ) points (equal to 1 *SD* on the Peabody).

Table 9

Number of large adjacent changes in fine motor scores¹ for infants with low gross motor scores and those in the comparison group

Group	Number of large DMQ changes (>15)				Total
	0	1	2	3 or >	
Low scoring GM	11 (55%)	9 (45%)	0	0	20
Comparison	48 (61%)	25 (32%)	6 (8%)	0	79
Total	59	34	6	0	99

Note. GM = gross motor.

¹Defined as >15 Developmental Motor Quotient (DMQ) points, which equals 1 *SD* on the Peabody.

Table 10

Correlation coefficients for gross and fine motor scores

Age	GM/FM	
	Total low scoring group (<i>n</i> = 33)	Low scoring both domains (<i>n</i> = 10)
9 months	-.386*	-.305
11 months	.140	-.259
13 months	.070	.258
16 months	.332	.330
21 months	-.205	.348

Note. GM = gross motor; FM = fine motor.

**p* = .027.

Table 11

Scoring change in one motor domain during periods of substantial developmental lag^a in the other motor domain

	Second motor domain scoring	
	Prior motor score ^b	Concurrent motor score
Low GM scoring occasions ^c (<i>n</i> = 21)	94.57 (9.66)	88.57 (10.57)
Low FM scoring occasions ^d (<i>n</i> = 19)	87.16 (14.98)	83.37 (13.82)

Note. GM = gross motor; FM = fine motor.

^aScores < 85 with prior scores at least 10 points higher were selected for analysis

^bPeabody Developmental Motor Quotient (DMQ) scores in the second domain were used

^cLow GM scoring occasions were obtained from the scores of infants in the low GM scoring group

^dLow FM scoring occasions were obtained from the scores of infants in the low FM scoring group

Figure 1 (a – d).

Examples of developmental trajectories for the four gross motor clusters

Figure 1a.

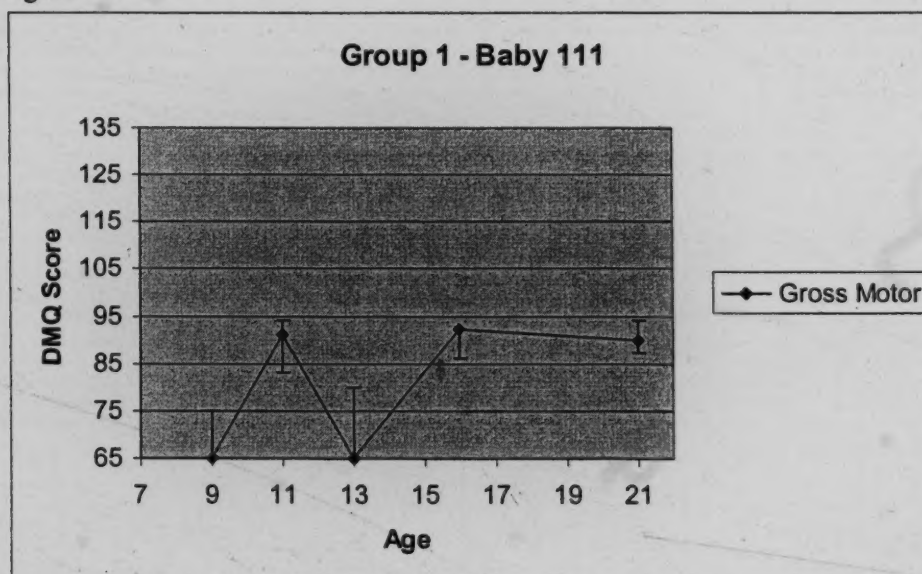


Figure 1b.

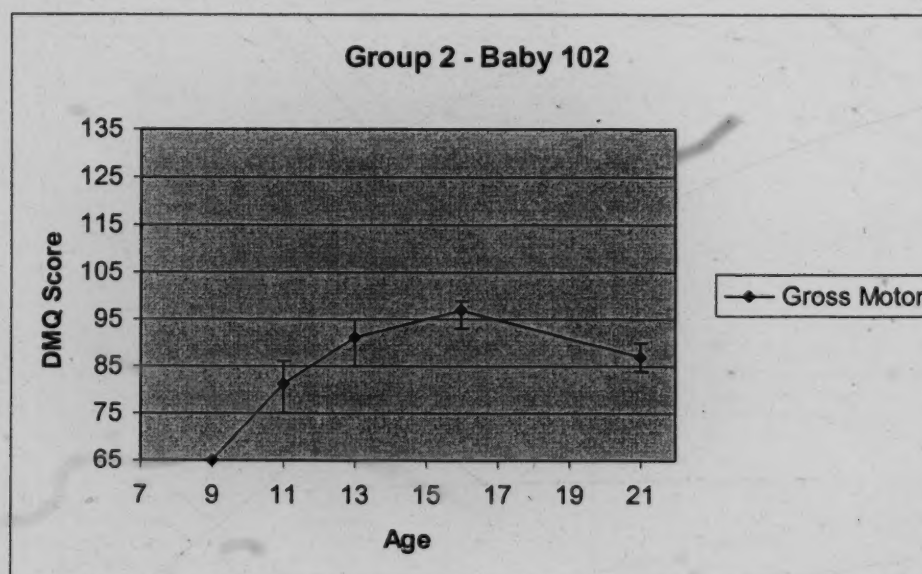


Figure 1c.

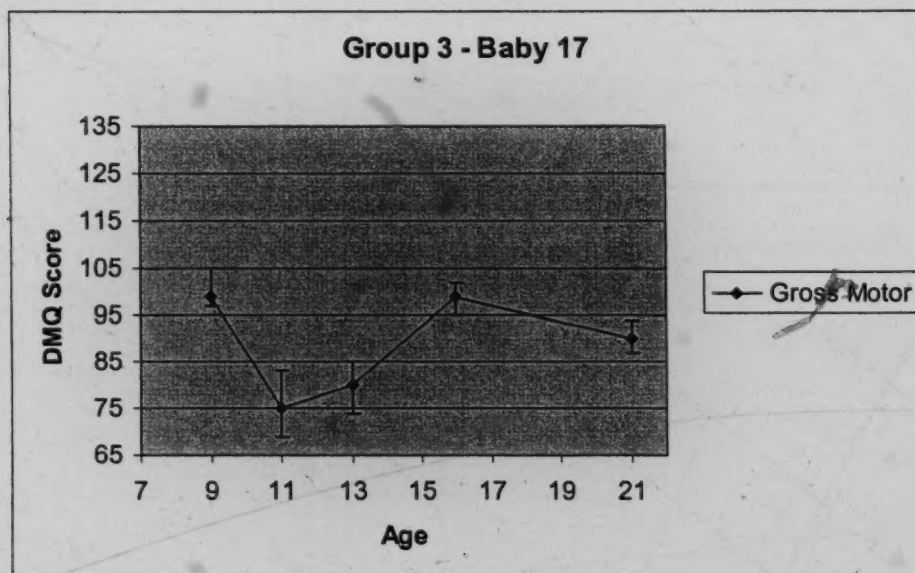


Figure 1d.

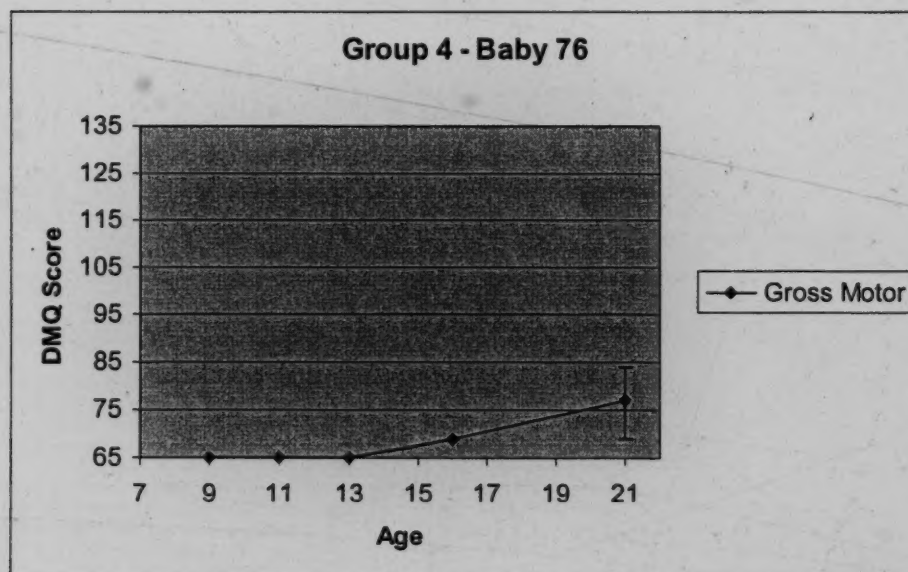


Figure 2 (a – c).

Similar fine motor profiles from three different clusters

Examples of three fine motor profiles that were sorted into three different clusters but appeared to be clinically similar.

Figure 2a.

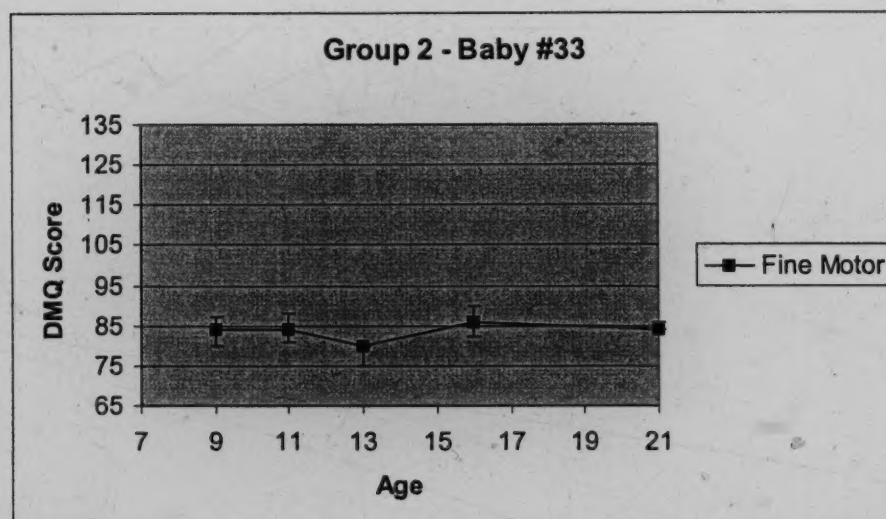


Figure 2b.

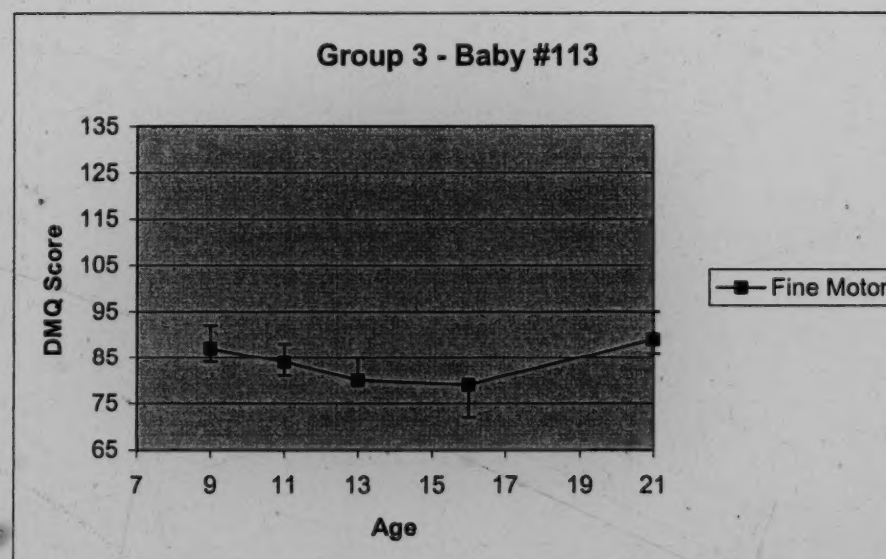


Figure 2c.

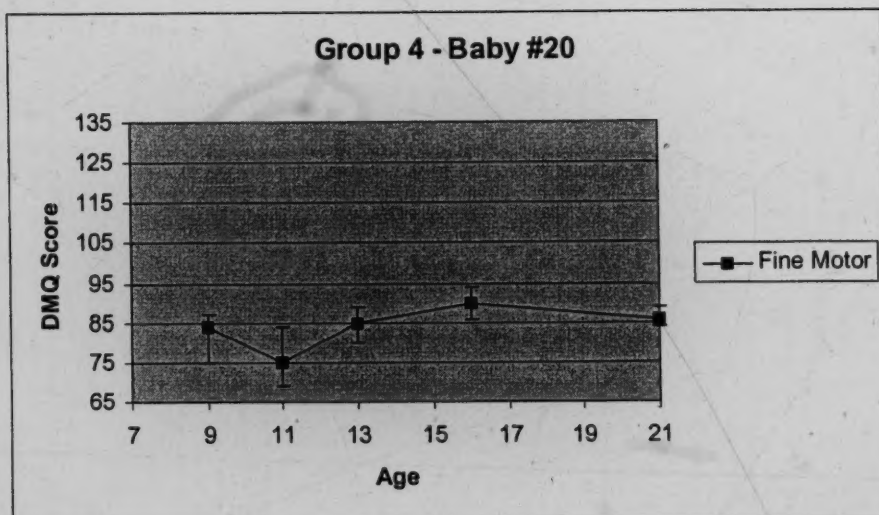


Figure 3.

Corresponding fine and gross motor profiles

Examples of corresponding fine motor profiles for four infants with similar gross motor profiles: parallel (3a); opposite (3b), combination of parallel and opposite (3c) and stable (3d).

Figure 3a.

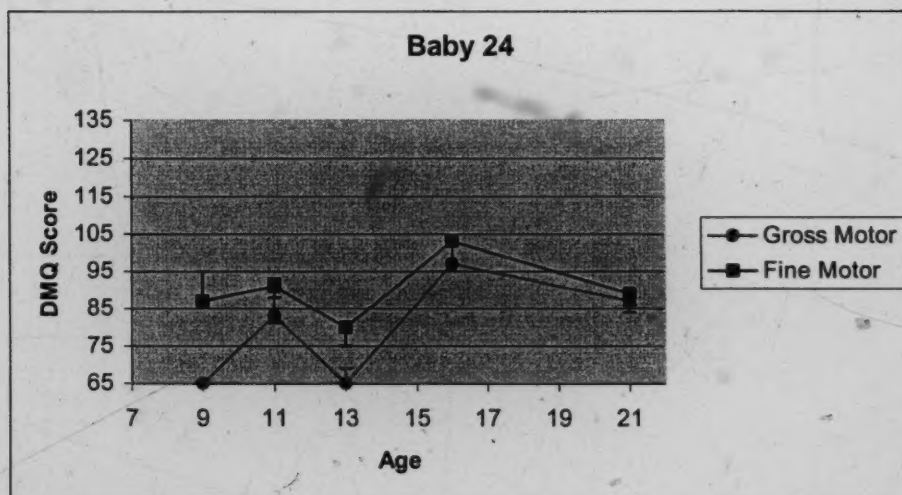


Figure 3b.

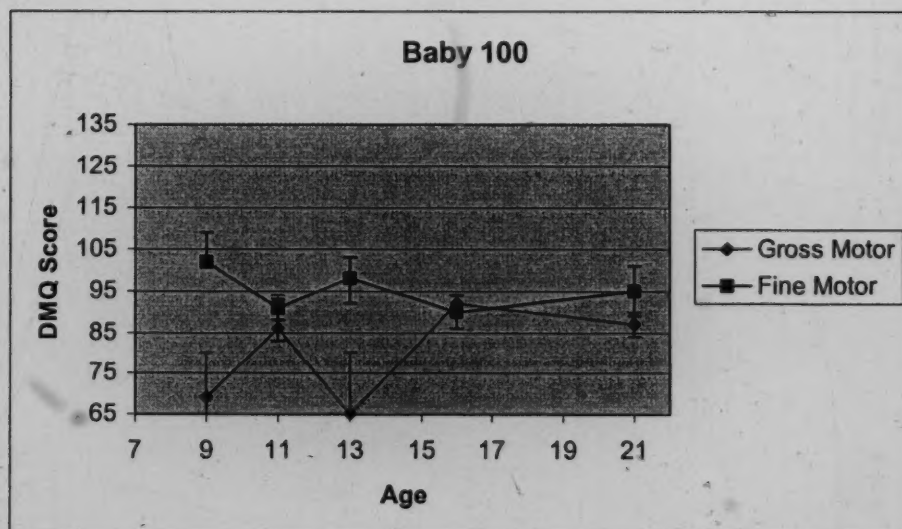


Figure 3c.

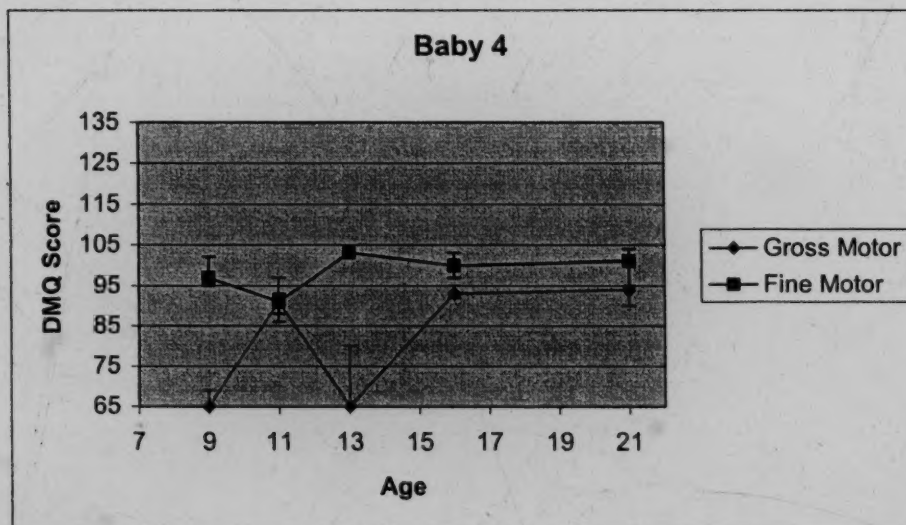
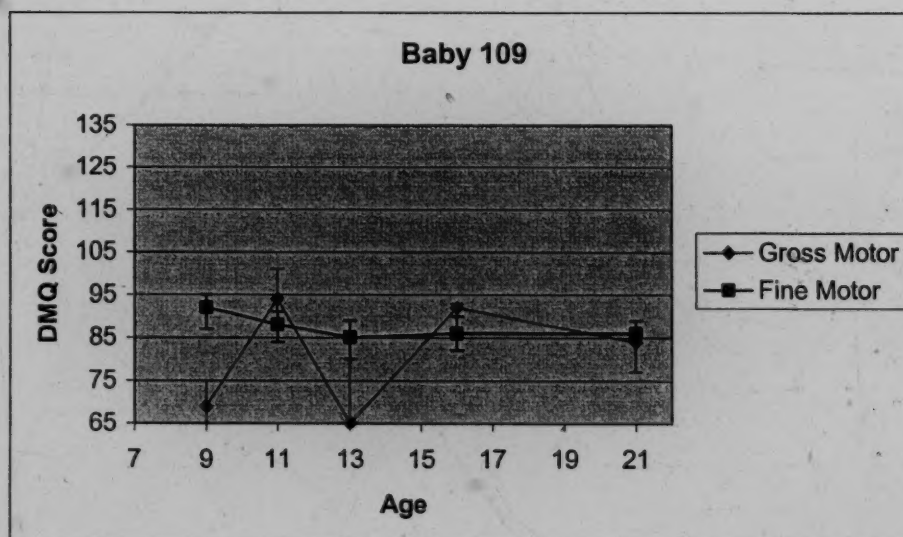


Figure 3d.



APPENDIX B

Screening Interview - At time of recruitment

1. Explain the purpose of the study and the type of children that we are looking for.

Longitudinal; visits in the home, come to campus. Looking at how children develop in three different areas. If agree, research assistants would come when the child is 8, 10, 12, 15, 18, 24 for communication assessments and 8, 10, 12 for motor assessments. Assessments at 15, 18 and 24 months and a final assessment at 28 months on campus. Assessments are like games; an hour for each visit, two visits at each age.

2. Willing to participate: Yes _____ No _____

Will be asked to sign a consent form at time of first visit

3. Name of parent and child:

4. Screening criteria

Need to make sure that you and your child meet the criteria, ask some questions

Born close to due date (37 wks. GA) _____ Healthy baby (no major anomalies, NICU) _____

No disabilities or medical conditions _____

No concerns about the way in which child is developing _____

Speaks English to the baby _____ Reads English at Grade 8 level _____

If all positive responses proceed.

5. Child's birthdate: _____

6. Availability: days of the week most appropriate _____

Time of day: _____

(When child is most likely to be alert and not hungry)

Tentative assessment time and date: _____

Will call to confirm prior to visit to make sure it is still convenient and that the child is healthy. Give them phone number to call if something comes up.

7. Any special directions for finding home:

8. Phone Number: Home _____ Work _____

9. Any questions?

APPENDIX C

Family Number _____

GENERAL INFORMATION QUESTIONNAIRE
(Completed at 8 month visit)Description of your child

1. Has your child been hospitalized since birth? _____
If yes, at what age and why? _____
2. Has your child been ill (e.g., ear infections, pneumonia) since birth? _____
If yes, at what age(s)? _____

Please describe the illness(es)

3. Has your child had any problems requiring attention by a specialist? _____
If yes, please describe _____
When did these problems start? _____
Have these problems ended? _____ If yes, when? _____
4. Your child's ethnic background is: _____

Description of your family

1. Number of children living in your home: _____

List the year of birth for each of these children:

- a) _____ b) _____ c) _____
d) _____ e) _____ f) _____

2. Yearly Family Income:

- | | | | |
|-----------------------|-------|--------------------|-------|
| a) less than \$20,000 | _____ | b) \$20,000-29,999 | _____ |
| c) \$30,000-39,999 | _____ | d) \$40,000-49,000 | _____ |
| e) \$50,000-59,999 | _____ | f) \$60,000-69,999 | _____ |
| g) \$70,000-79,000 | _____ | h) \$80,000 & over | _____ |

Mother:

1. Are you currently working for pay? Yes _____ No _____

If yes,

On average, how many hours per week do you work? _____ hours

Please describe your job.

(Title) Description: _____

2. How many years of full-time education have you completed? _____

3. Your highest level of education:

Graduate school degree _____
College or university graduation _____
Partial college/specialized training _____
High school graduate _____
Partial high school _____
Junior high school _____

Father:

1. Are you currently working for pay? Yes _____ No _____

If yes,

On average, how many hours per week do you work? _____ hours

Please describe your job.

(Title) Description: _____

How many years of full-time education have you completed? _____

2. Your highest level of education:

Graduate school degree _____
College or university graduation _____
Partial college/specialized training _____
High school graduate _____
Partial high school _____
Junior high school _____

APPENDIX D

Family Number _____

GENERAL HEALTH & PARENTING INFORMATION
(Completed at each visit)

1. Has your child been hospitalized since my last visit? _____
If yes, why?

2. Has your child been ill (more than a cold) since my last visit? _____

If yes, describe the illness(es) _____

Did the problem require attention by a specialist? _____

If yes, give details: _____

3. Do you have any concerns about your child's development?

4. Have you taken any parenting courses/ attended any parent-child programs since my last visit?

If yes, please describe.

APPENDIX E

(U of A letterhead)

Information Letter

Title of Project: Evaluation of Infant Development

Principal Investigator: Dr. Johanna Darrah, Physical Therapy, University of Alberta, 492 -9142

Co- Investigators: Dr. Megan Hodge, Speech Pathology & Audiology, 492 -5898
Dr. Joyce Magill-Evans, Occupational Therapy, 492- 0402
Dr. Keith Goulden, Glenrose Rehabilitation Hospital, 471-7918
Dr. Lynn Redfern, Public Health Sciences, U of A/Alberta Health, 415-2784

Purpose of the Project: To examine whether motor and communication development is stable or unstable in children during the first two years of life.

Background: We are doing this study to increase our knowledge about how infants develop. Our results will improve early intervention programs for developmentally delayed infants in two ways.

1. Our findings may result in fewer infants being falsely identified as developmentally delayed in the screening process for early intervention.
2. Our results will help to design and evaluate interventions for infants who are delayed in gross motor (e.g., sitting, walking), fine motor (e.g., reaching, picking up toys) and communication skills.

We are following 120 children from 8 months to 28 months of age.

Procedures: Qualified therapists will assess your child at 8, 10, 12, 15, 18 and 24 months of age. Each assessment will involve two visits, one day apart. Each visit will take about one hour. We will schedule the visits at a convenient time for you.

At the first visit, we will assess your child's gross and fine motor skills. We will also ask you about any illness or circumstance that may affect how your child does during the assessment. We will ask you for some general information on parent education and family income.

The second visit will focus on communication. At this visit, we will videotape how your child communicates.

All of the visits to look at your child's communication skills will be in your home. Assessments of your child's motor skills will also be in your home at 8, 10, and 12 months of age. The assessments for motor skills at 15, 18 and 24 months will be at Corbett Hall at the University of Alberta. We need to use specific stairs and balance boards at these ages. We will pay your parking or transportation costs for the visits to Corbett Hall.

When your child is 28 months old, you will come to Corbett Hall for a quick 15-minute assessment. This will confirm that your child is developing like most children. Again, we will pay your parking or transportation costs.

Summary of the visits:

AGE	8, 10 & 12 months (2 visits at each of these ages)		15, 18 & 24 months (2 visits at each of these ages)		28 months
VISIT	Visit 1	Visit 2	Visit 1	Visit 2	Visit 1
WHERE	Home	Home	Corbett Hall	Home	Corbett Hall
TIME	1 hr	1 hr	1 hr	1 hr	15 min.
Description of Assessment	motor skills	communication skills	motor skills	communication skills	motor & communication skills

Risks and Benefits: There are no risks to you or your child. All assessments are non-invasive. One benefit to you is that you will learn about your child's motor and communication development. Another possible benefit is that therapists will monitor your child's development over the course of the study. If they have any concerns, they will refer you to your family doctor.

The general knowledge we gain about how children develop will assist health and education professionals. They will be better able to identify and help children whose development is not typical.

Confidentiality: All the information that we obtain about you, your child and your family is confidential except when professional codes of ethics and or legislation require reporting. We will store all written materials and videotapes in a locked file cabinet. The data will be stored for seven years. Only the investigators and their research staff will have access to this information. We will not publish any information that could identify you, your child or your family.

If we do any further analysis with this study, we will first obtain further ethical approval.

Freedom to Withdraw: You are free to refuse to take part in this study. You are free to refuse to answer any questions for this study. If you decide to take part, you are free to withdraw from this study at any time. Your refusal or withdrawal will not affect future care for yourself or your family.

Additional Contacts: If you have any concerns about this study, you may contact the Patient Concerns Office of the Capital Health Authority at 474-8892. This office has no affiliation with study investigators.

Thank you for considering taking part in this study.

Sincerely,

Johanna Darrah, PhD
Assistant Professor

Megan Hodge, PhD
Associate Professor

Joyce Magill-Evans, PhD
Associate Professor

APPENDIX F

(U of A letterhead)

CONSENT FORM

Title of Project: **Evaluation of Infant Development**Principal Investigator(s): **Dr. Johanna Darrah, Physical Therapy, 492- 9142**Co-Investigator(s): **Dr. Megan Hodge, Speech Pathology & Audiology, 492- 5898****Dr. Joyce Magill-Evans, Occupational Therapy, 492- 0402****Dr. Keith Goulden, Glenrose Rehabilitation Hospital, 471-7918****Dr. Lynn Redfern, Public Health Sciences, U of A, Alberta Health, 415 -2784****Part 2 (to be completed by the research subject):**

Do you understand that you and your child have been asked to be in a research study? Yes No

Have you read and received a copy of the attached Information Letter? Yes No

Do you understand the benefits and risks involved in taking part in this research study? Yes No

Have you had an opportunity to ask questions and discuss this study? Yes No

Do you understand that you are free to refuse to participate or withdraw from the study at any time? You do not have to give a reason and it will not affect your child's or your family's care. Yes No

Has the issue of confidentiality been explained to you? Do you understand who will have access to your and your child's information? Yes No

Do you want the investigator(s) to inform your family doctor that you are participating in this research study? If so, please provide your doctor's name: Yes No

This study was explained to me by: _____

I agree to take part in this study.

Signature of Research Participant_____
Date_____
Witness_____
Printed Name_____
Printed Name

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

Signature of Investigator or Designee_____
Date

THE INFORMATION LETTER MUST BE ATTACHED TO THIS CONSENT FORM AND A COPY GIVEN TO THE RESEARCH SUBJECT

APPENDIX G

Health Research Ethics Board

biomedical research

health research

212-27 Walter Mackenzie Centre
University of Alberta, Edmonton, Alberta T6G 2B7
p.780.492.9724 f.780.492.7303
ethics@med.ualberta.ca

3-45 Carleton Hall, University of Alberta
Edmonton, Alberta T6G 2G4
p.780.492.0839 f.780.492.1626
ethics@www.rehabmed.ualberta.ca

UNIVERSITY OF ALBERTA HEALTH SCIENCES FACULTIES,
CAPITAL HEALTH AUTHORITY, AND CARITAS HEALTH GROUP

HEALTH RESEARCH ETHICS APPROVAL

Date: July 2002

Name of Applicant: Ms. Cynthia Tom

Organization: University of Alberta

Department: Occupational Health

Project Title: Motor skills in Infancy: Exploring the Instability Observed in Typical Development

The Health Research Ethics Board (HREB) has reviewed the protocol for this project and found it to be acceptable within the limitations of human experimentation. The HREB has also reviewed and approved the subject information letter and consent form.

The deliberations of the HREB included all elements described in Section 50 of the *Health Information Act*, and found the study to be in compliance with all the applicable requirements of the Act.

The approval for the study as presented is valid for one year. It may be extended following completion of the yearly report form. Any proposed changes to the study must be submitted to the Health Research Ethics Board for approval. Written notification must be sent to the HREB when the project is complete or terminated.

Sharon Warren

Dr. Sharon Warren
Chair of the Health Research Ethics Board (B: Health Research)

File number: B-170702-REM

